

**IMPROVED DOUBLE-TUBE APPARATUS FOR USE IN A HEAT EXCHANGER
AND METHOD OF USING THE SAME**

Field of the Invention

[0001] The present invention relates generally to the field of heat exchangers and specifically to heat exchangers having concentric tubular members for preventing mixing between fluids involved in the heat exchange.

Background of the Invention

[0002] A simple heat exchanger consists of a shell containing a large number of tubes with fluid flowing inside and outside the tubes. The fluid flowing inside the tubes is known as tube-side fluid whereas the fluid flowing outside the tubes is known as the shellside fluid. During normal operation, heat will be transferred from the hotter fluid, through the walls of the tube, and into the cooler fluid. Depending on the relative temperatures of the fluids and the desired result, heat can be transferred either to or from the tube-side fluid flow.

[0003] In certain industrial applications, mixing between the shellside and tubeside fluid leads to violent and/or hazardous chemical reactions and/or the creation of toxic or flammable fluids. In such application mixing between the tubeside and shellside fluids must be prevented. Double-tube heat exchangers have been developed to protect against this danger. In a double-tube heat exchanger, the shellside fluid flows outside an outer tube. The tubeside fluid flows inside the inner tube. The inner tube is positioned within and concentric to the outer tube so that an interstitial space exists between the inner tube and the outer tube. The interstitial space is usually filled with an inert fluid. The inert fluid can be stagnant or designed to flow through the interstitial space. In the event of a leakage, the inert fluid flows into the shellside or the tubeside thereby preventing mixing between the shellside and tubeside fluids. An example of such a double-tube heat exchanger is disclosed in U.S. Patent 4,538,674, Schluderberg, which is hereby incorporated by reference in its entirety.

[0004] While existing double-tube heat exchangers help protect against the mixing of the tube-side fluid and the shell-side fluid, a major problem of such heat exchangers has been the ability

to properly support the inner tube within the outer tube. In existing systems, the inner tubes are either not properly supported within the outer tube or are supported in such a way that fluid flow of the inert fluid through the interstitial space is impeded. Additionally, existing systems are very complicated, difficult and expensive to manufacture. Thus, a need exists for a double-tube apparatus for use in heat exchanger system that properly supports the inner tube within the outer tube without seriously impeding the ability of the inert fluid to flow through the interstitial space.

[0005] An additional problem with existing double-tube heat exchangers is that impeded flow of fluid through the interstitial space reduces the ability to transfer heat between the tubeside fluid and the shellside fluid. Thus, there is a further need for a double tube apparatus for use in a heat exchanger system that improves heat transfer capabilities.

Disclosure of the Invention

[0006] These and other problems are solved by the present invention which in one aspect is an apparatus for use in a heat exchanger system comprising: an inner and outer tube, the inner tube extending through the outer tube so as to form an interstitial space; and a ridge located between an outside surface of the inner tube and an inside surface of the outer tube, the ridge contacting the inside surface and the outside surface at specified locations so as to form a fluid passageway through the interstitial space. The ridge contact points are designed to eliminate flow induced vibration. The ridge is preferably helical in shape and extends the entire length of the interstitial space formed between the outer and the inner tube. The ridge can be installed on the outside surface of the inner tube or the inside surface of the outer tube.

[0007] By providing contact between the inner and outer tubes within the interstitial space, the ridge helps support the inner tube within the outer tube while still maintaining a fluid flow passageway through the interstitial space. As such, the inner tube is more robustly supported within the outer tube without seriously impacting the flow of fluids through the interstitial space, thereby improving heat transfer capabilities. When the ridge is helical in shape, the ridge will further improve heat transfer capabilities of the double tube apparatus. The helical ridge forces the fluid through the interstitial space along a helical passageway, increasing the amount of time the fluid is in surface contact with the outside surface of the inner tubular member. The amount of heat transferred to the fluid in the interstitial space is thereby increased.

[0008] It is further preferable that the inner tube extend through at least the entire length of the outer tube. In an alternative embodiment, the apparatus can further include a second helical ridge located between the outside surface of the inner tube and the inside surface of the outer tube. As with the first ridge, the second helical ridge will contact both the inside surface of the outer tube and the outside surface of the inner tube so as to form a second fluid passageway through the interstitial space. This second helical ridge will add further support for the inner tube and provide a greater area of contact between the inner and outer tube, thereby further increasing heat transfer through conduction.

[0009] The selection of the inner and outer tube material is based on the fluid/tube material compatibility. The inner and outer tubes can be constructed of a variety of heat exchanger tube materials including but not limited to steel, copper, brass, iron, aluminum, titanium and zirconium. In such an embodiment, the ridge should also be constructed of a metal that is compatible with the tubeside fluid and the shellside fluid and can be attached to either the inner or outer tube.

[0010] In another aspect, the invention is a heat exchanger system incorporating the above described double-tube apparatus. Specifically, in this aspect, the invention is a heat exchanger system comprising: a shell containing an outer tube, an inner tube positioned within the outer tube so as to form an interstitial space between the inner tube and the outer tube; a ridge located between an outside surface of the inner tube and an inside surface of the outer tube, the ridge contacting the inside surface of the outer tube and the outside surface of the inner tube so as to form a fluid passageway through the interstitial space. The shell has openings for supplying and discharging a shellside fluid that flows outside the outer tubes, an annular ring having openings for supplying and discharging an inert fluid to the interstitial space, and a channel/bonnet having openings for supplying and discharging a tubeside fluid that flows through the inner tube.

[0011] In order to prevent mixing between the tubeside fluid flowing through the inner tube and the shellside fluid flowing outside the outer tube, the system will preferably include means to supply the inert fluid to the interstitial space at a pressure higher than the pressures of the tubeside and shellside fluids. As such, if a leak develops in the inner or outer tubes, the inert fluid will flow outward from the interstitial space, reducing the possibility that the tubeside and shellside fluids will come into contact with one another. In order to detect the presence of a leak

in the system, the system preferably comprises a means to monitor the pressure within the interstitial space, such as a pressure sensor. In this embodiment, a controller is preferably coupled to the pressure detection means and an alarm. The controller is programmed to trigger an alarm upon receiving a signal indicating a pressure drop within the interstitial space from the sensor.

[0012] The system also preferably includes outer tube sheets for supporting the inner tubes. These outer tube sheets are designed so as to allow only the tubeside fluid to flow through the inner tubes. Inner tube sheets are also preferably provided for supporting the outer tubes. These inner sheet are located adjacent to and between the outer tube sheets and are positioned so as to allow only the inert fluid to flow into the interstitial space between the outer and inner tubes. A plurality of baffles can be provided in the shell between the inner tube sheets. A single system will preferably incorporate a plurality of the double-tube apparatus within a single shell. The specific preferred characteristics of the double-tube apparatus discussed above can be incorporated into the system.

[0013] In yet another aspect, the invention is a method for cooling or heating fluids comprising: an apparatus comprising an outer tube, an inner tube extending through the outer tube so as to form an interstitial space, a ridge located between an outside surface of the inner tube and the inside surface of the outer tube, the ridge contacting the inside surface of the inner tube and the outside surface of the inner tube so as to form a fluid passageway through the interstitial space; the tubeside fluid flowing through the inner tube; the shellside fluid flowing outside the outer tube, an inert fluid supplied to the interstitial space. The inert fluid can be flowing through the interstitial space or stagnant therein.

[0014] The inert or interstitial fluid must be compatible with the tubeside and shellside fluids and the inner and outer tube materials. The inert fluid is application and material sensitive.

Brief Description of the Drawings

[0015] FIG. 1 is a side view of a heat exchanger according to an embodiment of the present invention.

[0016] FIG. 2 is a cross-sectional view of the heat exchanger of FIG. 1 showing a concentric tube apparatus according to an embodiment of the present invention positioned therein.

[0017] FIG. 3 is a perspective view of a section of the concentric tube apparatus shown in FIG. 2.

[0018] FIG. 4 is a top view of a section of an embodiment of the inner tube of the concentric tube apparatus of FIG. 3.

[0019] FIG. 5 is a cross sectional view of the concentric tube apparatus of FIG. 3 taken along line V-V.

Modes for Carrying Out the Invention

[0020] Referring first to FIG. 1, heat exchanger 10 is illustrated according to an embodiment of the present invention. Heat exchanger 10 comprises a cylindrical shell 11 having flanges 12 at its ends. End covers 13 are secured to flanges 12 to form a tubeside chamber 14 (FIG. 2). End covers 13 can be secured to flanges 12 by welding, bolting, or any other means known in the art. Alternatively, shell 11 can be formed so as to have end covers 13 integrally formed. However, it is preferable that covers 13 be removable from shell 11 for access into tubeside chamber 14 (FIG. 2) for repair or replacement of the parts therein. Shell 11 and covers 13 should be made from a material that is resistant to the tubeside fluid being used.

[0021] Heat exchanger 10 has a number of outlets and inlets 15-20. Outlets and inlets 15-20 form passageways through shell 11 so that fluids can pass into or out of different constituent chambers of tubeside chamber 14 (FIG. 2). More specifically, heat exchanger 10 includes tube-side fluid inlet 17, tube-side fluid outlet 20, shell-side fluid inlet 16, shell-side fluid outlet 18, interstitial fluid inlet 15, and interstitial fluid outlet 19. As used herein, the term fluid includes both liquids, gases, and combinations of the two.

[0022] Referring now to FIG. 2, shell 11 is divided into numerous chambers along its length. These chambers include tube-side fluid spaces 21, intermediate fluid spaces 22, and shell-side fluid space 23. Tube-side fluid spaces 21 are hermetically separated from the rest of the spaces by outer tube sheets 24. Intermediate fluid spaces 22 are formed between, and hermetically separated from the rest of the spaces by outer tube sheets 24 and inner tube sheets 25. Inner tube sheets 25 form shell-side fluid space 23. A plurality of baffles 26 are provided within shell-side fluid space 23. Concentric tube apparatus 40 is positioned within the shell 11. Concentric tube apparatus 40 comprises inner tube 41 and outer tube 42. Inner tube 41 extends through outer tube 42 forming an interstitial space 43 therebetween.

[0023] Referring now to FIGS. 3 and 4, concentric tube apparatus 40 comprises inner tube 41 and outer tube 42. Inner tube 41 extends through outer tube 42 forming an interstitial space 43 there between. Outer tube 42 has opening 45 extending through its entire length. Outer tube 42 has a smooth outside surface 48 and smooth inside surface 49 (FIG. 5). Inner tube 41 has opening 46 extending through its entire length. A helical ridge 44 is formed onto the outside surface 47 of inner tube 41. Inner tube 41 and helical ridge 44 are sized so that inner tube 41 can fit within and extend through opening 45 of outer tube 42.

[0024] Referring now to FIGS. 3 and 5, when inner tube 41 is positioned within and extends through opening 45 of outer tube 42, an interstitial space is formed between the outside surface 47 of inner tube 41 and the inside surface 49 of outer tube 42. Interstitial space 43 extends the entire length of outer tube 42. Inner tube 41 and helical ridge 44 are sized so that helical ridge 44 contacts inside surface 49 of outer tube 42 along the top surface of the helical ridge 44 when assembled. When inner tube 41 extends through the opening 45 of outer tube 42, helical ridges 44 forms a helical passageway through the interstitial space that allows fluid to pass through the entire length of interstitial space 43. In addition to forming a helical passageway through interstitial space 43, helical ridge 44 acts to support inner tube 41 within outer tube 42 and acts to maintain the existence of interstitial space 43.

[0025] While the ridge 44 on the outside surface 47 of inner tube 41 is illustrated as a single helix, the invention is not so limited. The ridge can take on any shape, including a plurality of straight ridges or a plurality of semi-circular ridges spaced along the length of the inner tube. Additionally, a second helical ridge can be added to form a second helical passageway through the interstitial space. Moreover, it is not necessary to form the ridge onto the outside surface of the inner tube. Alternatively, the ridge can be a separate piece or formed onto the inside surface of the outer tube. By ensuring that the ridge contacts both the inside surface of the outer tube and the outside surface of the inner tube, heat can be transferred between the two tubes through conduction. Preferably, the ridge is welded or brazed to the surfaces. Increasing the contact area of the ridge with the surfaces of the inner and outer tubes will increase heat transfer by conduction.

[0026] Finally, the helical ridge is not limited to any specific pitch. The pitch of the helical shape can be varied depending on system requirements. Inner tube 41 can be constructed of a

material compatible with the tubeside fluid, shellside fluid and interstitial fluid. The ridge is made from material that is compatible with the tubeside fluid, the shellside fluid, and the inner and outer tubesheet materials.

[0027] Referring again to FIG. 2, concentric tube apparatus 40 is positioned in chamber 14 of shell 11. Specifically, outer tube sheets 24 support inner tube 41 in a center portion of chamber 14. Inner tube 41 extends through the entire length of outer tube 42. The ends of inner tube 41 are connected to outer tube sheets 40 so as to form a hermetically sealed fluid passageway between tube-side fluid spaces 21 through opening 46 of inner tube 41. As such, tubeside fluid 50 can flow into tube-side fluid inlet 17, through opening 46 of inner tube 41, and out through tube-side fluid outlet 20. It is a common practice to put the hazardous or toxic fluid through the inner tubes.

[0028] Outer tube 42 is supported within chamber 14 by inner tube sheets 25. The ends of outer tube 42 are connected to inner tube sheets 25 so as to form a fluid passageway between intermediate fluid spaces 22 through interstitial space 43. Interstitial space 43 forms a fluid passageway between intermediate fluid spaces 22. As such, inert fluid 51 flows into interstitial fluid inlet 52, through interstitial space 43 (along the helical passageway formed by helical ridge 44), and out through interstitial fluid outlet 19.

[0029] Baffles 26 are provided in shell-side fluid space 23. Preferably, the helical ridge 44 (FIG. 3) extends along the entire length of interstitial space 43 formed between inner tube 41 and outer tube 42. This helps support the inner tube 41 within the outer tube 42 while still allowing the inert fluid 51 to pass through the interstitial space with minimal obstruction.

[0030] Shell-side inlet 52 is used to permit the flow of shellside fluid 52 into shell-side fluid space 23. Upon entering shell-side fluid space 23, the shellside fluid 52 will contact the outside surface 48 (FIG. 5) of the outer tube 42. The shellside fluid 52 exits the shell-side fluid space 23 through shell-side fluid outlet 18. The shellside fluid 52 is usually the non-hazardous, non toxic fluid intended to cool or heat the tubeside fluid. Depending on the requirements of the system, heat will be either transferred to the shellside fluid 52 from the tubeside fluid 50 or vice versa.

[0031] Finally, it is preferable that the inert fluid 51 flowing through the interstitial space be at a pressure greater than the pressures of the tubeside and shellside fluids 50, 52. This can be done using a pump and/or valving system. Providing the inert fluid 51 at a higher pressure than the

tubeside and shellside fluids **50, 52** helps prohibit the mixing of the tubeside and shellside fluids **50, 52** in the event of a leak. If a leak occurs in either inner tube **41** or outer tube **42**, inert fluid **51** will respectively flow either into inner tube **41** or into shellside fluid space **23**. The increased pressure will prohibit tubeside and shellside fluids **50, 52** from flowing into interstitial space **43**. As a safety feature, pressure sensor **60** (generically illustrated as a rectangle in FIG 2) is provided within intermediate fluid space **22**. Alternatively, pressure sensor **60** can be provided within interstitial space **43** itself. Pressure sensor **60** measures the pressure within intermediate fluid space **22** (which is the same as the pressure in interstitial space **43**) and transmits a data signal indicating the pressure reading to a properly programmed processor (not illustrated). The processor analyzes the data and compares the measurement to a pre-programmed set value. If the pressure reading is below the pre-programmed critical value, as would be the case if there was a leak, the processor will send a signal to an alarm that will be activated, informing an operator that there is a problem. Optionally, the processor can be programmed to shut down the heat exchanger **10** in a safe fashion.

[0032] While the invention has been described and illustrated in sufficient detail that those skilled in this art can readily make and use it, various alternatives, modifications, and improvements should become readily apparent without departing from the spirit and scope of the invention.